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Draft Recommended Practice For Fiber Optic Local and Metropolitan Area Networks

Sponsor

LAN MAN Standards Committee
of the
IEEE Computer Society

This is Draft 3.1 of the proposed 802.8 standard for the LAN/MAN Standards Committee of the IEEE Computer Society. It incorporates changes to the third draft which was the subject of a Working Group Letter Ballot and was circulated to voluntary reviewers from other 802 working groups. Draft 3.1 will be the subject of an LMSC Sponsor Ballot.

INTRODUCTION

(This introduction is not part of **Draft** IEEE Std 802.8 but is included for information only.)

Standard Introduction and Figure will be added by IEEE editors.

This recommended practice arose from the need to provide guidance above and beyond that contained in the formal requirements of the IEEE 802 standards. It is analogous to IEEE 802.7 Recommended Practice for Broadband Local Area Networks, and is designed to prevent common design and installation errors that impinge on the performance of an IEEE 802 network.

PARTICIPANTS

The following participants were members in the Recommended Practices effort of the IEEE Project 802.8 working group. Those names followed by an asterisk (*) were voting members at the time of approval of IEEE 802.8, Revision X.

J. Paul Benson, Jr., **Chair** Kenneth C. Taylor, **Vice Chair**

This book is dedicated to Stephen W. Janshego who passed away April 7, 1995. He was the driving force behind this recommended practice and will be fondly remembered by his associates for his friendship, support, and enthusiastic attitude.

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RECOMMENDED PRACTICES FOR FIBER OPTICS

1. OVERVIEW

1.1 SCOPE

This recommended practice provides a common set of recommendations to physically configure, loss budget, and test fiber optic implementations of IEEE 802 local and metropolitan area networks. It applies to P802 implementations that incorporate LED optical sources. Physical configurations are related to standardized cable distribution systems. The loss budget design process applies to all approved 802 multimode fiber LED-based PMD sublayers. Test methods ensure compliance to 802 fiber optic path loss requirements and check installation integrity.

1.2 PURPOSE

The purpose of this recommended practice is to provide users and implementers of IEEE 802 local and metropolitan area networks with a common set of practices for multimode fiber optic media.

1.3 DOCUMENT ORGANIZATION

This recommended practice is organized into the following major clauses:

Clause 3 (Definitions). This clause contains the definitions of terms that have special meaning for this recommended practice.

Clause 4 (Abbreviations and Acronyms). This clause contains abbreviations and acronyms that have special meaning for this recommended practice.

Clause 5 (Structured Cable Plant Implementation). This clause describes commonly used structured cabling systems and provides guidance in configuring these systems to implement IEEE 802 networks.

Clause 6 (Loss Budget Design). This clause presents a design process to predict whether specific configurations will meet IEEE 802 requirements for cable plant loss.

Clause 7 (Testing and Certification). This clause recommends test methods and test criteria to evaluate installed cable plant.

1.4 OVERVIEW OF THE MEDIA

In a physical sense, a cable plant distribution system is an arrangement of components in an ordered structure to support a variety of network topologies.

A cable plant distribution system consists of various families of components, including transmission media, circuit administration hardware, connectors, jacks, plugs, adapters, transmission electronics, electrical protection devices, and support hardware. These components are used to build subsystems, each having a specific purpose, that allow easy implementation and smooth transition to enhanced network distribution technology as communications requirements change. In the case of a fiber optic system, the medium for the interconnection of those subsystems is optical fiber cable.

2. NORMATIVE REFERENCES

This recommended practice shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

ANSI/EIA-455-34-85, FOTP-34 Interconnection Device Insertion Loss Test.

ANSI/EIA/TIA-455-46A-90, FOTP -46 Special Attenuation Measurement for Long-Length, Graded-Index Optical Fibers.

ANSI/EIA-455-50A-87, FOTP-50 Light-Launch Conditions for Long-Length Graded-Index Optical Fiber Spectral Attenuation Measurements.

ANSI/EIA/TIA-455-61-89, FOTP 61 Measurement of Fiber or Cable Length Using an OTDR.

ANSI/EIA-455-171-87, FOTP-171 Attenuation by Substitution Measurement - For Short-Length Multimode Graded-Index and Single-Mode Optical Fiber Cable Assemblies.

ANSI/EIA/TIA-455-180-91, FOTP-180 Measurement of the Optical Transfer Coefficients of a Passive Branching Device (Coupler).

ANSI/EIA/TIA-526-14A-to be published 1998, OFSPT-14 Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant.

ANSI/TIA/EIA-568-A-95, Commercial Building Telecommunications Cabling Standard.

IEC 1280-2-1: to be published 1998, Receiver Sensitivity and Overload Measurement.

IEEE Std 100-1996, IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).

IEC 793-2: 1989, Optical fibers, Part 2: Product specifications.

IEEE Std 812-1984, IEEE Standard Definitions of Terms Relating to Fiber Optics (ANSI).

IEEE Std 802.3u: 1995 [ANSI/IEEE Std 802.3u, 1996 Edition], Media Access Control (MAC) Parameters, Physical Layer, Medium Attachment Units, and Repeater for 100 Mb/s Operation, Type 100BASE-T (Clauses 21-30).

IEEE Std 802.12: 1995 [ANSI/IEEE Std 802.12, 1995 Edition], IEEE Standards for Local and Metropolitan Area Networks: Demand Priority Access Method, Physical Layer and Repeater.

ISO/IEC 8802-3: 1993 [ANSI/IEEE Std 802.3, 1993 Edition], Information technology—Local and metropolitan area networks—Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.

ISO/IEC 8802-4: 1990 [ANSI/IEEE Std 802.4, 1990 Edition], Information Processing System—Local area networks—Part 4: Token - passing bus access method and physical layer specifications.

ISO/IEC 8802-5: 1995 [ANSI/IEEE Std 802.5, 1995 Edition], Information Technology—Local and metropolitan area networks—Part 5: Token ring access method and physical layer specifications.

ISO/IEC 9314-3: 1990, Fiber Distributed Data Interface (FDDI) - Token Ring Physical Layer Medium Dependent (PMD).

ISO/IEC 11801: 1995Information Technology - Generic cabling for customer premises

3. DEFINITIONS

This clause contains the definitions of terms and abbreviations that have special meaning or that are unique to the technical content of this recommended practice.

active: A component that consumes electrical power to perform its intended function.

passive: A device that does not require power and contains no active components.

configuration: The functional and physical characteristics of hardware or software as set forth in technical documentation or achieved in a product.

patch cord: A length of fiber optic cable with connectors on both ends used to join telecommunications links/circuits at the cross connect.

topology: The physical or logical arrangement of a telecommunications system.

4. ABBREVIATIONS AND ACRONYMS

ANSI	American National Standards Institute
BER	Bit Error Ratio
EIA	Electronic Industries Association
FO	Fiber Optic
FOTP	Fiber Optic Test Procedure
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
LAN	Local Area Network
LED	Light Emitting Diode
NA	Numerical Aperture
OFSTP	Optical Fiber System Test Procedure
OTDR	Optical Time Domain Reflectometer
TIA	Telecommunications Industry Association

5. STRUCTURED CABLE PLANT IMPLEMENTATION

5.1 802 NETWORK TOPOLOGIES

The topology of a system is the logical interconnection of the nodes. Point-to-point, active and passive stars, and ring topologies are used in 802 Fiber Optic communications systems.

5.2 PHYSICAL CONFIGURATION

Physical configuration is the arrangement of components of a network in a building or a cluster of buildings. To achieve a particular topology, the cable plant distribution system is the means by which the physical configuration is implemented. A cable plant distribution system consists of various families of components, including transmission media, circuit administration hardware, connectors, splices, attenuators, couplers, electrical protection devices, and support hardware.

Small networks, consisting of a single active hub or a single ring are straightforward to conceive, design and implement. Larger networks are more complex in nature, consisting of a hierarchy of node connections to a hub or repeater, with these units connected by backbone links. A well designed distribution system is relatively independent of the equipment it serves, and is capable of interconnecting many different LANs, communication devices, data terminals, computers etc. ISO/IEC 11801: 1995 and TIA/EIA-568A-1995 provide detailed guidance regarding how to design such a distribution system. These documents establish structured cabling plans to facilitate building cabling in a generic fashion such that they can be configured to implement LAN's of IEEE 802 equipment by the use of hubs, repeaters, and/or patch cords.

These documents, while using different terminology, both describe a consistent, hierarchical approach to building cabling shown schematically in Figure 1. They define maximum lengths of both the fixed building cabling and the associated patch cords (see Table 1), as well as the fiber parameters (see Table 2).

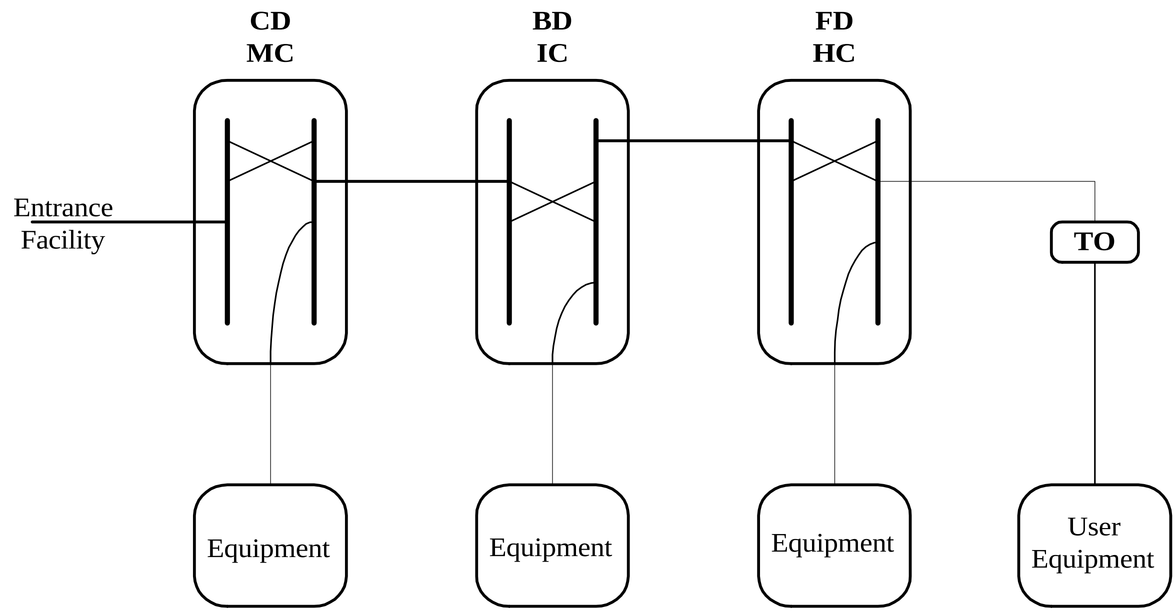

Figure 1 – Generic Cabling Diagram

Table 1 – Distribution System Cabling Distances

Configuration	Installed cable length (m)	Total patch cord length (m)	Total Inter-equipment length (m)
FD-CD (IEC)	2000	35	2035
HC-MC (TIA)	2000	36	2036
FD-BD-CD (IEC)	500+1500=2000	55	2055
HC-IC-MC (TIA)	500+1500=2000	56	2056
FD-BD (IEC)	500	35	535
HC-IC (TIA)	500	36	536
User-BD (IEC)	590	40	630
User-IC (TIA)	590	40	630
User-FD (IEC)	90	10	100
User-HC (TIA)	90	10	100

	ISO/IEC terminology	TIA terminology
Where:	FD = Floor Distributor	HC= Horizontal Cross connect
	CD= Campus Distributor	MC= Main Cross Connect
	BD= Building Distributor	IC= Intermediate Cross Connect
	TO= Telecommunications Outlet	TO= Telecommunications Outlet

Table 2 – Fiber parameters

Property		TIA-568A-1995	ISO/IEC-11801: 1995
Attenuation: (dB/km)	850 nm	3.75	3.5
	1300 nm	1.5	1.0
Modal Bandwidth: (MHz*km)	850 nm	160	200
	1300 nm	500	500

To implement an IEEE 802 network in a building cabled according to one of these standards, the relevant IEEE specification parameters must be mapped onto the installed cable plant to determine the proper location for hubs, repeaters, etc. IEEE 802 specification parameters are summarized in Table 4 and Table 5. Note that certain maximum distances allowed by both TIA-568A-1995 and ISO/IEC-11801: 1995 nominally correspond to maximum distances allowed (proposed) by IEEE 802 standards. The total length allowed for the configurations exceeds the 802 distances limits by the combined patch cord length.

IEEE 802 specification limits are based on several factors, including not only attenuation, but dispersion and topology constraints such as propagation delay. For example, 802.3 topology rules are formulated to limit the size of contention domains to ensure robust operation of the protocols. To rigorously ensure that a cable plant conforms to the requirements of the relevant IEEE 802 specifications, system designers should reduce the maximum installed cable lengths by the combined patch cord length such that the total distance between active devices conforms to the limits set forth in Table 4 and Table 5.

Note that while it may be possible to "stretch" the standards by running equipment over lengths which exceed the specifications slightly, such operation is not guaranteed. Also, failure modes may not be simply Bit Error Ratios (BER) which are a little too high, but rather more subtle system throughput degradation which may be extremely difficult to diagnose.

6. LOSS BUDGET DESIGN

This clause describes the loss budget design process for IEEE 802 fiber optic links that incorporate LED sources. A link consists of the passive fiber optic media between an optical transmitter and an optical receiver. Each IEEE 802 fiber optic standard specifies minimum and maximum path losses to ensure that sufficient but not excessive power is delivered to the optical receiver. Insufficient or excessive power can cause the BER to increase or, in the extreme, link transmission to fail. The goal of loss budget design is to predict expected optical path losses. In order to satisfy optical path loss specifications and physical layout constraints, the loss budget process has the flexibility to trade off items such as link length, number of connectors, and number of splices.

Because loss budget design predicts optical path loss it does not, in and of itself, assure that a specific link, once installed, will meet requirements. End-to-end loss measurements, which are discussed in clause 7.3, are the only method to confirm an installed link meets loss requirements.

6.1 LOSS BUDGET EQUATIONS

Figure 2 is a schematic diagram of a generic fiber optic link. While the diagram is not meant to represent any particular 802 link, a star coupler[1] is included to demonstrate how it is treated in the design process. An optical transmitter, an optical receiver, patch cord cables, multifiber cables, connectors, splices, and a star coupler make up the link shown in Figure 2. The transmitter optical output appears at a connector as does the receive optical input. Patch cord cables are typically used to connect 802 equipment to a wall outlet or to crossconnect cables in a wiring closet. Multifiber cables are used in the horizontal and backbone subsystems. Outside plant, building, or both cable types may be required. Splices provide permanent connections between two optical fibers. Connectors provide changeable connections between two optical fibers or allow a fiber to be connected to a transmitter, receiver, or star coupler.

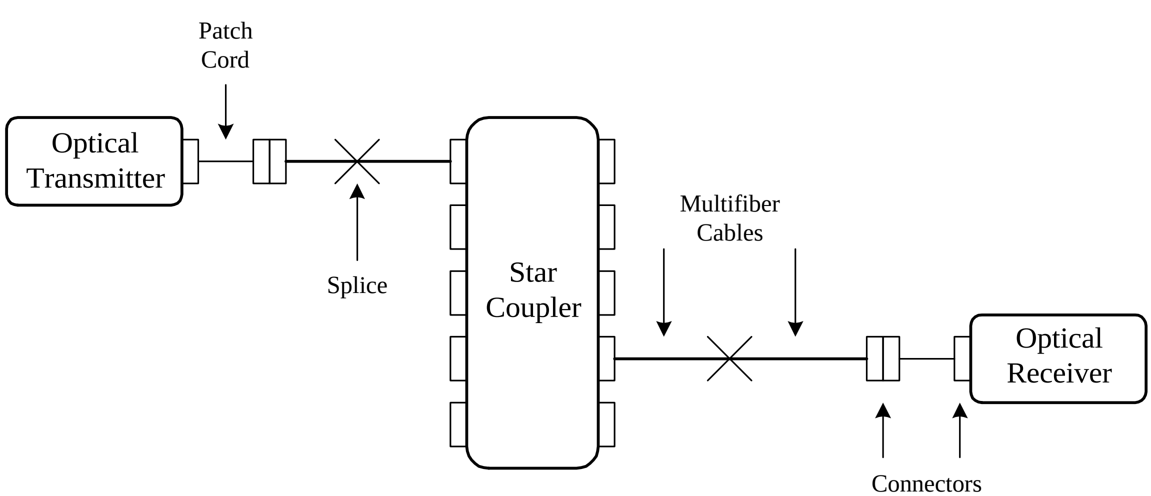

Figure 2 – Generic Fiber Optic Link

[1]Star couplers are used in 802.3 10BASE-FP.

The loss budget design process cannot begin until the link length, cable and patch cord lengths, type and quantity of splices and connectors, fiber attenuation and loss of each fiber optic component, transmitter output power, and receiver input power are known. It is important to consider any possible future expansion, relocation, and reconfiguration of the link when determining cable lengths and splice and connector quantities. Component parameters obtained from manufacturers should be representative of current production as measured according to standard test methods listed in Table 3.

Individual 802 standards specify parameters for the fiber optic link and certain fiber optic components. Parameters that pertain to the loss budget design are maximum link length, fiber type, cabled fiber attenuation, connector type, connector loss and return loss, transmitter output power, and receiver input power. Link loss difference, and passive star loss and uniformity pertain only to 10BASE-FP fiber optic links. These parameters are summarized in Table 4 and Table 5. While 62.5/125 µm (core/cladding diameter) multimode optical fiber is recommended, alternate sizes are permitted. The individual standards should be consulted for guidance if an alternate fiber is used. It should be noted that connector types are only specified at the equipment interface. The user has the option of specifying other connector types for the remainder of the fiber optic link.

Table 3 – Loss Budget Parameters

Item	Parameter	Standard Test Method
Link	length	
Transmitter	output power range	none available
Receiver	input power range	IEC 1280-2-1
Outside plant cables	type total length of each type attenuation of each type expected minimum operating temperature	 FOTP 60 FOTPs 46, 50, & 61
Building cables	type total length of each type attenuation of each type	 FOTP 60 FOTPs 46, 50, & 61
Patch cord cables	total length attenuation	 FOTP 171 method B1
Splices	type loss of each type expected minimum operating temperature	 FOTP 34 method A2
Connectors	type loss of each type expected minimum operating temperature	 FOTP 34 method A2
Passive star	number of ports insertion loss port non-uniformity expected operating temperature	 FOTP 180ro

Table 4 – 802 Fiber Optic Link Parameters

Parameter	FOIRL	10BASE-FB	10BASE-FL	10BASE-FP	100BASE-FX
GENERAL					
link length, max (km)	1	2		1	2
FIBER (62.5/125)					[2]
standard	IEC 793-2 type A1b				
core diameter (µm)					62.5
clad diameter (µm)					122.0 to 128.0
NA					0.275
attenuation @ 850 nm, max (dB/km)	3.75				
attenuation @ 1300 nm, max (dB/km)					
bandwidth @ 850 nm, min (MHz*km)	160				
bandwidth @ 1300 nm, min (MHz*km)					500[2]
l_0 (nm)	1320 to 1365				[2]
S_0, max (ps/nm²*km)	0.11 for l_0 (1320 to 1348) (1458- l_0)/1000 for l_0 (1348 to 1365)				[2]
CONNECTOR					
type	FSMA	ST simplex		ST simplex	SC duplex
standard	IEC 874-1,2	IEC 61754-2		IEC 61754-2	IEC 61754-4.2
loss, max (dB)	2.5			1.0	
return loss, min (dB)				25	
TRANSMITTER					
l_c (nm)	790 to 860	800 to 910		800 to 910	1270 to 1380
l_w FWHM, max (nm)	75	75		75	ISO/IEC 9314-3
output power (dBm)	-9 to -18	-12 to -20		-11 to -15	-14 to -20
RECEIVER					
receive power (dBm)	-9 to -27	-12 to -32.5		-27 to -41	-14 to -31
FIBER OPTIC PATH					
loss (dB)	0 to 9	0 to 12.5		16 to 26	0 to 11
loss difference, max (dB)				6	
system return loss, min (dB)				27	
PASSIVE STAR					
insertion loss (dB) includes one connector pair				16 to 20	
port nonuniformity, max (dB)				2.5	
directivity, min (dB)				35	

[2] Fiber properties for 100BASE-FX are specified by reference to FDDI (ISO/IEC 9314-3: 1990). l_0 and S_0 are defined therein by an envelope (Figure 14) which applies to any fiber size. Values listed for 10BASE-F and FOIRL describe a portion of the FDDI envelope which pertains to 62.5 micron fiber.

Table 5 – 802 Fiber Optic Link Parameters

Parameter	802.4	802.5	802.12	
GENERAL				
link length, max (km)		2	0.5	2
FIBER (62.5/125)			[3]	
standard		IEC 793-2 type A1b	IEC 793-2 type A1b	
core diameter (µm)	62.5			
clad diameter (µm)	125			
NA	0.275	0.275 ± 0.015		
attenuation @ 850 nm, max (dB/km)		3.75	3.5	
attenuation @ 1300 nm, max (dB/km)			1.0	
bandwidth @ 850 nm, min (MHz*km)		160	200	
bandwidth @ 1300 nm, min (MHz*km)			500	
l_0 (nm)				
S_0 (nm)				
CONNECTOR				
type	FDDI duplex	SC duplex	SC duplex	
standard	IEC 61754-12	IEC 61754-4.2	IEC 61754-4.2	
loss, max (dB)			0.75	
return loss, min (dB)			20	
TRANSMITTER				
l_c (nm)	800 to 910	800 to 910	800 to 900	1270 to 1380
l_w FWHM, max (nm)	60	75	100	200
output power (dBm)	-7 to -11	-12 to -19	-12 to -20	-14 to -22
RECEIVER				
receive power (dBm)	-11 to -31 (M) -21 to -41 (H)	-12 to -32	-12 to -27.5	-14 to -29
FIBER OPTIC PATH				
loss (dB)	4 to 20 (M) 14 to 30 (H)	0 to 13	0 to 7.5	0 to 7
loss difference, max (dB)				
system return loss, min (dB)				
PASSIVE STAR	parameters not specified, but included in path loss			
insertion loss (dB) includes one connector pair				
port nonuniformity, max (dB)				
directivity, min (dB)				

[3] Fiber properties for 802.12 are specified by reference to ISO/IEC 11801: 1995.

As stated above, the loss budget design process ensures sufficient but not excessive power is delivered to the optical receiver. This goal is realized if the following inequalities are satisfied.

$$Pt_{max} - Pr_{max} \leq Lm_{min} \quad \text{(excessive condition)}$$

and

$$Pt_{\min} - Pr_{min} \geq Lm_{max} \quad \text{(sufficient condition)}$$

where:

Pt_{max} & Pt_{min} = maximum and minimum transmitter output powers (dBm) coupled into the fiber.

Pr_{max} & Pr_{min} = maximum and minimum receiver input powers (dBm) coupled from the fiber.

and

Lm_{max} & Lm_{min} = maximum and minimum losses (dB) of the interconnecting fiber optic media.

Two different methods can be used to calculate the expected loss of the interconnecting media (Lm): statistical and worst case. The statistical method is based on the low probability that worst case values for system components will occur simultaneously for all components in a single link. Each link component is modeled as an independent normally distributed random variable. The interconnecting media loss is equal to the summed mean component losses plus or minus a constant times the quadrature sum of the components standard deviations. Adding the quadrature sum to the mean losses yields Lm_{max}, subtracting yields Lm_{min}. The constant determines the level of confidence that the interconnecting media loss is bounded by Lm_{max} and Lm_{min} and that the link will operate properly. Table 6 gives the confidence levels for three values of constant. Statistical methods can provide a more efficient use of resources than worst case methods, however they require information which may not be readily available except to turn-key providers.

Table 6 – Statistical Model Confidence Levels

Constant	Confidence Level (%)
1	84.13
2	97.72
3	99.86

The worst case method ensures all links will operate properly. Worst case or maximum loss values for each component are summed to calculate Lm_{max}, and "best case" or minimum values are summed to calculate Lm_{min}.

Equations (1) and (2) are used to calculate Lm_{max} and Lm_{min}, respectively. Mean (μ) and standard deviation (σ) loss values are used for each link component in the statistical method. If statistical values for a component are not available, then the worst or best case loss is substituted for the mean, and zero (0) is substituted for the standard deviation. In the extreme where no statistics are known, the statistical method degenerates to the worst case method. To use the worst case method, maximum values are substituted for the mean terms in equation (1) and minimum values are substituted in equation (2). Standard deviation terms are set to zero (0) in equations (1) and (2).

$$\begin{aligned} Lm_{max} = {} & H + m_{JC} l_{JC} + l_C\left(m_C + m_{CT} + m_{lH}\right) + N_{CO}\left(m_{CO} + m_{COT}\right) \\ & + N_S\left(m_S + m_{ST}\right) + \left(m_{SC} + m_{SCT}\right) + C\Bigg[\left(s_{JC} l_{JC}\right)^2 + \left(s_C^2 + s_{CT}^2\right)\sum_{i=1}^{n} l_{Ci}^2 \\ & + N_{CO}\left(s_{CO}^2 + s_{COT}^2\right) + N_S\left(s_S^2 + s_{ST}^2\right) + \left(s_{SC}^2 + s_{SCT}^2\right)\Bigg]^{\frac{1}{2}} \end{aligned} \quad \textbf{(1)}$$

$$\begin{aligned} Lm_{min} = {} & m_{JC} l_{JC} + l_C\left(m_C - m_{lL}\right) + N_{CO} m_{CO} + N_S m_S + m_{SC} \\ & - C\left[\left(s_{JC} l_{JC}\right)^2 + s_C^2 \sum_{i=1}^{n} l_{Ci}^2 + N_{CO} s_{CO}^2 + N_S s_S^2 + s_{SC}^2\right]^{\frac{1}{2}} \end{aligned} \quad \textbf{(2)}$$

where:

$H =$ High order mode loss (dB). This term accounts for the preferential attenuation of high order modes in multimode systems. Typical values range between 0.5 dB for LED sources that fully fill the fiber and 0.0 dB for laser sources.

$C =$ Constant to determine confidence level.

$m_{JC},\ s_{JC} =$ Mean and standard deviation of patch cord cable attenuation (dB/km).

$l_{JC} =$ Total patch cord cable length (km).

$l_{Ci} =$ Sheath length of ith cable (km).

$l_C = \sum_{i=1}^{n} l_{Ci} =$ Total sheath length of n cables (km).

$m_C,\ s_C =$ Mean and standard deviation of cable attenuation (dB/km) at the end of cable lifetime and at the wavelength where cable attenuation is specified. Sigma should include an allowance for the supplier's loss measurement uncertainty.

$m_{CT},\ s_{CT} =$ Mean and standard deviation of the effect of temperature on cable loss (dB/km) at the worst case temperature conditions over the expected cable operating temperature range.

$m_{lH} =$ Increase in mean cable attenuation (dB/km) above m_C at the wavelength within the 802 allowed range of transmitter center wavelengths at which the largest mean loss occurs. (See 6.2)

$m_{lL} =$ Decrease in mean cable attenuation (dB/km) below m_C at the wavelength within the 802 allowed range of transmitter center wavelengths at which the lowest mean loss occurs. (See 6.2)

$N_{CO} =$ The total number of connectors.

m_{CO}, $s_{CO} =$ Mean and standard deviation of connector loss (dB).

m_{COT}, $s_{COT} =$ Mean and standard deviation of the effect of temperature on connector loss (dB) at the worst case operating temperature.

$N_S =$ The total number of splices.

m_S, $s_S =$ Mean and standard deviation of splice loss (dB).

m_{ST}, $s_{ST} =$ Mean and standard deviation of the effect of temperature on splice loss (dB) at the worst case operating temperature.

m_{SC}, $s_{SC} =$ Mean and standard deviation of star coupler loss (dB). These losses should include one connector pair.

m_{SCT}, $s_{SCT} =$ Mean and standard deviation of the effect of temperature on star coupler loss (dB) at the worst case operating temperature.

6.2 CABLE ATTENUATION CALCULATIONS

This clause describes methods for and examples of calculating m_{lH} and m_{lL} at short wavelengths (around 850 nm) and long wavelengths (around 1300 nm).

6.2.1 Short Wavelength Calculations

Fiber attenuation as a function of wavelength, at short wavelengths, can be modeled by

$$m = Al^{-4} + B$$

where:

$m =$ Fiber attenuation (dB/km).

$l =$ Optical wavelength (µm).

A and $B =$ Constants.

To compute m_{lH} and m_{lL}, attenuation values at two wavelengths must be known. These are available from cable manufacturers. With these values

$$A = \frac{m_{l1} - m_{l2}}{l_1^{-4} - l_2^{-4}} \quad \textbf{(3)}$$

where:

m_{l1} and m_{l2} = Attenuation at l_1 and l_2, respectively.

l_1 and l_2 = Wavelength (µm).

Now m_{lH} and m_{lL} can be computed.

$$m_{lH} = A\left(l_{Short}^{-4} - l_C^{-4}\right) \quad \textbf{(4)}$$

and

$$m_{lL} = A\left(l_C^{-4} - l_{Long}^{-4}\right) \quad \textbf{(5)}$$

where:

l_C = Wavelength where cable attenuation is specified (µm).

l_{Short} = Shortest wavelength in the transmitter’s center wavelength range (µm).

l_{Long} = Longest wavelength in the transmitter’s center wavelength range (µm).

The following example shows how the calculations would be performed for a 10BASE-FB system. This system has a center wavelength from 800 to 910 nm. Thus, l_C = 0.85 µm, l_{Short} = 0.80 µm, and l_{Long} = 0.91 µm. The cable manufacturer provided typical attenuation values at 0.85 µm and 0.88 µm of 2.96 and 2.58 dB/km, respectively. Substituting these values into equations 3, 4, and 5

$$A = \frac{2.96 - 2.58}{0.85^{-4} - 0.88^{-4}} = 1.531,$$

$$m_{lH} = 1.531\left(0.80^{-4} - 0.85^{-4}\right) = 0.80 \text{ dB/km, and}$$

$$m_{lL} = 1.531\left(0.85^{-4} - 0.91^{-4}\right) = 0.70 \text{ dB/km.}$$

6.2.2 Long Wavelength Calculations

The relationship between fiber attenuation and wavelength is more complex at long wavelengths because of an OH^- attenuation component at 1385 nm. For this reason, attenuation values should be obtained directly from the manufacturer. This example shows how m_{lH} and m_{lL} would be computed for an IEEE Std

802.12-1995 long wavelength system. This system has a transmitter center wavelength range from 1270 to 1380 nm. Cable attenuation is typically specified at 1300 nm.

The manufacturer provided the following information. Cable attenuation is specified at 1300 nm, which is l_C , and is 0.60 dB/km. Within the 802.12 wavelength range, an attenuation maximum of 0.80 dB/km occurs at 1380 nm, and an attenuation minimum of 0.59 dB/km occurs at 1320 nm. If

$m_{l\,max} =$ Maximum attenuation in the transmitter's center wavelength range (dB/km) and

$m_{l\,min} =$ Minimum attenuation in the transmitter's center wavelength range (dB/km), then

$m_{lH} = m_{l\,max} - m_C = 0.80 - 0.60 = 0.20$ dB/km, and

$m_{lL} = m_C - m_{l\,min} = 0.60 - 0.59 = 0.01$ dB/km.

7. TESTING AND CERTIFICATION

This clause discusses testing and certification of fiber optic media. It begins with test data that can be obtained from component vendors. Pre-installation cable tests are described next. Finally, installed media tests are discussed in terms of link or sub-link, type of test, and test criteria.

Acceptance and conformance tests have different objectives. An acceptance test determines whether the installed cable plant will support 802 systems. It can be considered a go/no-go test. A conformance test generally must meet a tighter range of specifications. It is used to determine whether the cable plant was properly installed and to identify defective components.

7.1 VENDOR PROVIDED TECHNICAL RESULTS

Vendors can provide test data on fiber optic media components. There are two types of component data, qualification and production. Component vendors normally qualify products to a specification: their own, that of a recognized standards body (TIA/EIA, ISO/IEC, etc), or that of a customer or third party. Qualification tests are destructive in nature and are performed on representative samples.

Production data are test results on each component. Production data cannot be provided on connectors and splices, since these are installed or configured in the field. Table 7 shows the type of vendor data that is available for each component.

Table 7 – Vendor Test Data

Component	Qualification	Production
Multifiber Cable	X	X
Patch cord Cable	X	X
Connector	X	
Splice	X	
Star Coupler	X	X

7.2 PRE-INSTALLATION ACCEPTANCE TESTS

Pre-installation tests are attenuation measurements of outside plant and building cables when they are received. Generally these measurements are made using an (OTDR) while the cable is on reel. The goal of these measurements is to identify cable damage or defects. Localized areas of high attenuation and, fiber breaks indicate cable damage. OTDR measurements are usually made in one direction from the outside end of the cable, since damage is more likely to occur on the outside end. A sample of fibers in each cable may be measured. However, OTDR measurements of all fibers in both directions certifies cable integrity.

7.3 INSTALLED MEDIA (FIBER) TEST

Attenuation and loss measurements on installed fiber optic media are performed to verify that components were installed correctly (conformance test) and that fiber optic links meet 802 requirements. (acceptance test). In some situations, a continuous transmitter to receiver link is available for testing, while in other situations only constituent sub-links are available. The latter situation occurs when flexible routing is incorporated in the cable plant design and final configuration via crossconnects and interconnects will be performed by the user.

OTDR attenuation measurements can be used to establish an as-installed baseline for each fiber optic link or sub-link. This baseline is valuable for future maintenance activities and should be part of the final documentation. OTDR measurements identify installation defects such as a high loss splice, pinched cable, broken fiber, etc. A link or sub-link may meet end-to-end loss criteria even though an individual constituent component may fail. This is important data since a high loss splice/connector or pinched cable could have a short lifetime.

End-to-end loss measurements are performed with an optical power meter, an optical source, and appropriate test patch cords. ANSI/TIA/EIA 526-14A (OFSTP-14A) (*to be published 1998, finished ballot at TIA*) provides excellent guidance on performing end-to-end loss measurements. Three methods are presented in OFSTP-14A. They differ in the way a reference power level is established. The method used depends on the manner by which the link or sub-link is terminated. Both ends of the link may terminate in connector couplings at wall outlets or patch panels, they may terminate in connector plugs at the equipment interface, or they may terminate in a combination of the two. Ideally, the optical source should be representative of that used in the particular 802 equipment in terms of center wavelength, spectral width, and source type (surface emitting LED, microlensed LED, edge emitting LED, etc). If the source type is unknown, or the cable plant is intended for use with all IEEE 802 implementations, then the source type should be Category 1 per OFSTP-14A.

7.3.1 Acceptance Test

As stated previously, end-to-end loss measurements are performed to verify that links meet IEEE 802 requirements. Acceptance criteria apply to continuous transmitter to receiver links. Full acceptance tests include any patch cords which attach equipment to the network, and should be performed per OFSTP-14A Method C. The appropriate acceptance criteria are the maximum and minimum path loss values from Table 4 and Table 5. For example, 16 and 26 dB are the criteria for a 10BASE-FP link. If the measured end-to-end loss meets acceptance criteria, the link will operate from a loss standpoint. However, meeting acceptance criteria does not necessarily evaluate installation quality or conformance to the loss budget design.

7.3.2 Conformance Test

Conformance criteria are calculated from loss budget equations 1 and 2 for each link or sub-link. Equation 1 is used to compute the maximum expected path loss. Equation 2 is used to compute the minimum expected path loss. Measured end-to-end losses should meet conformance criteria. Causes of non-conformance should be sought and rectified. Refer to OFSTP-14A for guidelines regarding which method to use based on how links, sub-links, and patch cords are configured.

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